International Symposium on Aviation Psychology - 2015

International Symposium on Aviation Psychology

2015

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Repository Citation

Sierra, E. A., & Buckley, M. (2015). Development of the Air Traffic Control Tower Alerts Standard. *18th International Symposium on Aviation Psychology*, 260-265.
https://corescholar.libraries.wright.edu/isap_2015/63

DEVELOPMENT OF THE AIR TRAFFIC CONTROL TOWER ALERTS STANDARD

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FAA HF-STD-008 Air Traffic Control Tower Alerts Standard specifies functional requirements, alarm and alert human interaction characteristics, and threshold levels in systems that use an alert mechanism to capture human attention in air traffic control tower environments. FAA HF-STD-008 was developed to address a shortfall in the general criteria for alerts found in FAA HF-STD-001 Human Factors Design Standard. FAA-HF-STD-008 was developed in three phases: literature review and draft development, subject matter expert working group review and development, and stakeholder comment and adjudication. The results of the work include specific requirements for alerts and additional evidence of a repeatable human factors standard development procedure. There were shortfalls in general human factors requirements that were addressed by a standard with more specific requirements. Although human factors standards and the standardization process of human factors areas are relatively new in the FAA, there has been increased recognition of the significance of human factors requirements for system design.

At the end of a solo cross country flight, a private pilot on final approach hears the following.

LOW ALTITUDE ALERT CESSNA THREE FOUR JULIET,
CHECK YOUR ALTITUDE IMMEDIATELY.

The pilot recognizes that an air traffic controller has issued the alert to her. Was she too close to terrain or was there some other obstruction? How much time does she have to climb or should she do nothing? Whatever her level of situation awareness, her safety depends on the course of action she takes.

In the scenario above, both the pilot and the controller have to recognize and assess the situation in complex conditions. The pilot in this fictitious scenario soon recognizes that she should climb because a controller has issued a safety alert. For the controller; workload, traffic volume, the quality and limitations of the radar system, and the available lead time to react are factors (FAA Order 7110.65V, Air Traffic Control) impacting her ability to quickly assess the situation. The controller is able to recognize this situation with the help of a Minimum Safe Altitude Warning (MSAW). The topic of this paper is how requirements analysis contribute to the design, development, and implementation of effective alarms and alerts.

The Federal Aviation Administration (FAA) Systems Engineering Manual (SEM) Version 1.0, states “The Next Generation Air Transportation System (NextGen) is a comprehensive overhaul of the National Airspace System (NAS) to make air travel more efficient and dependable, while ensuring each flight is as safe and secure as possible.” The FAA SEM describes the NAS as a System of Systems. The system engineering processes for completing the transformation to NextGen are described therein. The system engineering processes include Operational Concept Development, Functional Analysis, Requirements Analysis, Architectural Design Synthesis, and Cross-Cutting Technical Methods. The specific challenge reviewed in this paper is Requirements Analysis.

The FAA SEM continues, “Requirements Analysis is an iterative process that defines the essential system characteristics for all system components required for the product’s successful development, production, deployment, operation, and disposal.” Requirements Analysis is composed of two distinct activities: Requirements Development and Requirements Management. The approach described in this paper has a direct impact on both, but especially on Requirements Development. The activity develops functional requirements from the functions developed through the Functional Analysis Process. The authors’ approach, described herein, was to develop a standard, which is a primary input to the Requirements Development process.

According to Rodrick, Karwowski, and Sherehiy, “Unlike other fields, standards and the standardization process in human factors and ergonomics are relatively new” (Rodrick et al., 2012, p. 1512). This statement pertains to human factors standards for FAA applications. Until recently (see FAA HF-STD-002 Baseline Requirements for Color Use in Air Traffic Control Displays [3/26/2007]), FAA HF-STD-001 Human Factors Design Standard (2003) was the only FAA reference providing formal input to Requirements Development. Although FAA HF-STD-001 includes requirements for air traffic control and maintenance; human factors specialists had to further analyze, decompose, and derive specific requirements for each system implementation. For example, requirements for air traffic control would be further analyzed and perhaps extrapolated for Terminal versus En Route. For Terminal, requirements would be further analyzed for Terminal Radar Approach Control needs versus Airport Traffic Control needs - and so on.

This paper describes the analysis of requirements for FAA HF-STD-008 Air Traffic Control Tower Alerts Standard (8/8/2014). Standards developers developed FAA-HF-STD-008 in three phases: literature review and draft development, subject matter expert (SME) working group review and development, and stakeholder comment and adjudication. The developers identified and compiled a preliminary, foundation set of requirements for FAA HF-STD-008 from FAA HF-STD-001, and also from additional sources from the literature. The developers compiled new candidate requirements from the literature because of the age of FAA HF-STD-001, and also because more detailed requirements were needed to support specific implementations for the tower environment. The developers also gathered additional requirement inputs from a team of FAA SMEs consulted at several diffferent FAA Towers.

After the standard developers identified and captured requirements from the literature, they matched the requirement to the appropriate level in the standard. Next, FAA SMEs analyzed the requirements. The standards developers and FAA SMEs repeated the process until the requirements were stable. Finally, the standards developers sent out a draft FAA HF-STD-008 for stakeholder comment. The standards developers adjudicated the stakeholders' comments before publishing the standard.

The standard developers achieved two things. First, they developed a body of requirements for the design and implementation of alarms and alerts for systems supporting tower operations in the form of a published FAA HF-STD-008 Air Traffic Control Tower Alerts Standard (8/8/2014). Second, this work provided evidence of a repeatable human factors standard development procedure. This paper describes method and results in detail in the sections that follow.

Method

The standard developers began requirements development with a review of the literature. They reviewed government documents that included military, and non-military federal agency standards, handbooks, and specifications. They reviewed non-government publications from organizations such as the American National Standards Institute (ANSI) and the International Electrotechnical Commission (IEC). Standards developers also reviewed research on alarms and alerts. FAA HF-STD-008 lists applicable documents in Section 2 and references in Appendix B.

A spreadsheet was used to support Requirements Management during the processes of compiling, filtering, sorting, organizing for access, and evolution through SME review. Compared to other FAA programs, the size and complexity of this project was small. A spreadsheet sufficed to manage the number of requirements. The spreadsheet application was used to capture, compile, and track the evolution of requirements. The spreadsheet was also used to maintain source documents traceability to the evolving requirements.

The standards developers identified and captured requirements from the literature in the spreadsheet. Next, the standards developers analyzed, filtered and sorted requirements for the tower environment. FAA SMEs, a group of FAA Senior Scientific & Technical Advisors for Human Factors and Senior Engineers, reviewed the requirements and further analyzed and evaluated them for applicability, accuracy, and conciseness. The standards developers and FAA SMEs repeated the analysis and evaluation in three successive reviews of succeeding drafts. Finally, the standards developers sent out the Draft FAA HF-STD-008 for stakeholder comment. The standards developers adjudicated the stakeholders' comments and submitted resolved comments for FAA review before drafting the final version of the standard.

Standard development took about a year. The standard developers identified and captured requirements from the literature within three months. They worked with FAA SMEs for six months. Public comment, adjudication, and FAA review took three months. This time frame did not include project planning and project management activities that were important, but occurred before and after standards development.

In addition to the literature review, FAA SME analysis and evaluation, and public comment; the standard developers used additional methods to enhance the viability of the product and ensure the validity of the requirements. Standard developers conducted tower facility visits with the Senior Scientific and Technical Advisor for Terminal. Standard developers also consulted with Engineering Research Psychologists and other specialists. These activities ensured that the standard developers more fully embraced and accommodated stakeholder needs, known constraints, current interface limitations, operating environments, and modes of operation.

There was one known limitation of the process as implemented. To allow for the best solutions for NextGen, requirements must be solution agnostic. For this effort , requirements were molded to facilitate unbiased and measurable evaluation of various solution alternatives. Standard developers analyzed and evaluated requirements for applicability to air traffic control, then for Terminal, and then once more for Airport Traffic Control. To be truly solution agnostic, Human factors specialists will need to also analyze and evaluate requirements for specifications of alerting systems such as MSAW, Conflict Alert (CA), or Far Field Monitor (FFM).

Results & Discussion

The method used by the standard developers performed well. During the literature review, a large number of candidate requirements were collected and compiled. During the FAA SME Review Phase, there were hundreds of suggested additions, simplifications, deletions and edits on the body of candidate requirments. By the time the draft was ready for stakeholder comment, most comments were administrative and very few were more than editorial in impact. That is, they addressed items such as typographical, format, and grammatical errors. There was also a fairly short cycle time from requirement change initiation to approved resolution. Finally, the number of validated requirements to total proposed requirements was not highly variable.

Enhancements for tower are summarized in Table 1.

Table 1.
FAA HF-STD-008 Alert Enhancements for Tower.

Property or Atttribute	FAA HF-STD-001: Chapter 7: Alarms, Audio & Voice Communications	FAA HF-STD-008
Coverage	High level, general coverage of alarms and alerts	Detailed coverage of all types of alarms and alerts for Tower operations
Focus	Audio and voice	Audio, visual and tactile requirements addressed
High-level organization	High-level coverage that addresses general functions and attributes, implementation concerns, and the intrinsic characteristics of audio and voice signals	Organized consistent with FAA-STD-068; includes a treatment for general and detailed requirements
Signal treatment	Audio-relevant requirements only	Includes non-modal-specific requirements
Signal characterization	Few characterization specifics	Detailed characterization and construction specifics

Property or Atttribute	FAA HF-STD-001: Chapter 7: Alarms, Audio & Voice Communications	FAA HF-STD-008
Implementation	Includes a few implementation-specific requirements	Includes a wide assortment of both non-modal-specific and modal-specific implementation requirments
Coding	Very few coding-specific requiremets	Many coding-specific requirements, including coding for each mode
System-specific treatment	Some equipment-specific treatment: controls, handsets, headsets, telephone systems	Generic system requirements relevant to alarms and alert systems in general

The method did address the problem, but not entirely. FAA HF-STD-008 Air Traffic Control Tower Alerts Standard (8/8/2014) will likely perform as intended. However, truly successful Requirements Development is measured by the acceptable transformation of stakeholder needs into discrete, verifiable, specific and applicable requirements. Many of these requirements will meet this criteria. However, the scope of FAA HF-STD-008 requires that human factors specialists further analyze and evaluate requirements for alert systems in light of changing needs and evolving technologies.

Consider requirement *4.1.1.3 Minimize response time*. The requirement reads, “An alarm and alert system must minimize the time required for the operator to detect and assess the situation and to initiate corrective action(s).” It is critical that human factors specialists analyze this requirement to enable requirements verification and compliance. The analysis may one day lead to a timely alert that the pilot in the introduction, and many others, will appreciate.

TRAFFIC ALERT CESSNA THREE FOUR JULIET,
ADVISE YOU TURN LEFT, AND CLIMB IMMEDIATELY.

As a final observation, the authors think it is important to note that the socialization of the content in the evolving standard ranked only slightly below the significance of the product’s final content. The mechanics of the three working group reviews of the draft in its successive forms started a conversation on component and philosophical issues that continued throughout the review process, culminating in the resolution of final comments following the wider stakeholder review. Each working group member received a copy of the latest draft for his examination prior to the meeting. Whether the working group members came prepared with a marked up copy with specific embedded comments, or just showed up with personal notes, questions and issues, each member had an opportunity to make sure the draft remained headed in the right direction. During the meeting, and with capture completed a short time later, all comments were captured in the Comments Resolution Matrix, giving each member direct feedback on the resolution of their concerns. Along the way, working group members became invested in the process and the product, sometimes becoming minor champions of specific decisions made during the evolution of the document.

Further, what was started with the working group reviews, continued in the wider stakeholder review. Though the working group numbered relatively few individuals, they were widely dispersed both organizationally and geographically. Widely networked, the fact that the working group played such a crucial role in the mechanics of the evolution of the standard surely benefitted participation during the final stakeholder review.

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Acknowledgements

FAA HF-STD-008 Air Traffic Control Tower Alerts Standard was developed with funding from FAA R&D Program, *A11.i Air Traffic Control/Technical Operations Human Factors*. This project was sponsored by Chuck Perala, Scientific & Technical Advisor at the Federal Aviation Administration. The authors gratefully acknowledge colleagues who assisted in developing the standard by actively participating in the working group reviews: Bert Howells (HumanProof), Charles Jones (AJW-131 Maintenance Automation Team), Chuck Perala (AJM-352 Specialty Engineering Team), Fred Brooks (National Institute of Aerospace), Jerry Crutchfield (AAM-500 Office of Aerospace Medicine - Aerospace Human Factors Division), Sehchang Hah (ANG-E25 Human Factors Branch), and Steve Cooley (AJM-352 Specialty Engineering Team). The authors are also grateful to FAA facility managers and tower controllers who hosted facility visits and to the aviation human factors community for their time reviewing and commenting on FAA HF-STD-008. The views of the authors do not necessarily reflect the views of the Federal Aviation Administration or HumanProof.